

1 **In the Claims**

2 No claims are canceled or added. Claims 46, 47, and 57 are amended.
3 Claims 1-5, 10, and 19-63 remain in the application for consideration and are
4 listed below:

5

6 1. **(ORIGINAL)** A facial expression transformation method
7 comprising:

8 defining a code book containing data defining a first set of facial
9 expressions of a first person;

10 providing data defining a second set of facial expressions, the second set of
11 facial expressions providing a training set of expressions of a second person who
12 is different from the first person;

13 deriving a transformation function from the training set of expressions and
14 corresponding expressions from the first set of expressions; and

15 applying the transformation function to the first set of expressions to
16 provide a synthetic set of expressions.

17

18 2. **(ORIGINAL)** The method of claim 1, wherein the training set of
19 expressions contains fewer expressions than the code book.

20

21 3. **(ORIGINAL)** The method of claim 1, wherein the transformation
22 function compensates for differences in the size and shape of the faces of the first
23 and second persons.

4. (ORIGINAL) The method of claim 1, wherein said deriving of the transformation function comprises computing a linear transformation from one set of expressions to another.

5. (ORIGINAL) The method of claim 1, wherein the deriving of the transformation function comprises:

representing each expression as a $3m$ -vector that contains x , y , z displacements at m standard sample positions; and

computing a set of linear predictors a_j , one for each coordinate of g_a , given a set of n expression vectors for a face to be transformed, $g_{a1\dots n}$, and a corresponding set of vectors for a target face, $g_{b1\dots n}$, by solving $3m$ linear least squares systems of the following form:

$$a_j \cdot g_{ai} = g_{bi}[j], i = 1 \dots n$$

6. (CANCELED).

7. (CANCELED).

8. (CANCELED).

9. (CANCELED).

10. (ORIGINAL) The method of claim 1, wherein said providing data defining a second set of facial expressions comprises:

illuminating the second person's face with illumination; and

1 contemporaneously capturing structure data describing the face's structure
2 and reflectance data describing reflectance properties of the face from the
3 illumination.

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5 **11. (CANCELED).**

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7 **12. (CANCELED).**

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9 **13. (CANCELED).**

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11 **14. (CANCELED).**

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13 **15. (CANCELED).**

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15 **16. (CANCELED).**

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17 **17. (CANCELED).**

18

19 **18. (CANCELED).**

20

21 **19. (ORIGINAL)** One or more computer-readable media having
22 computer-readable instructions thereon which, when executed by a computer,
23 cause the computer to:

24 operate on a training set of expressions from one person and corresponding
25 expressions from a code book of another person to compute a linear

1 transformation function from the training set and their corresponding expressions;
2 and

3 apply the transformation function to a plurality of expressions from the
4 code book to provide a synthetic set of expressions.

5
6 20. **(ORIGINAL)** The computer-readable media of claim 19, wherein
7 the instructions cause the computer to use the synthetic set of expressions to
8 transform expressions from the one person into expressions of the other person.

9
10 21. **(ORIGINAL)** The computer-readable media of claim 20, wherein
11 the instructions cause the computer to transform expressions from the one person
12 that are different from those expressions comprising the code book expressions.

13
14 22. **(ORIGINAL)** The computer-readable media of claim 20, wherein
15 the instructions cause the computer to transform expressions by transmitting at
16 least one index of a synthetic expression to a receiver that can reconstruct the
17 expression.

18
19 23. **(ORIGINAL)** The computer-readable media of claim 20, wherein
20 the instructions cause the computer to transform facial expressions.

21
22 24. **(ORIGINAL)** A facial expression transformation system
23 comprising:

24 a code book embodied on a computer-readable medium, the code book
25 containing data defining a first set of facial expressions of a first person;

1 data embodied on a computer-readable medium, the data defining a second
2 set of facial expressions, the second set of facial expressions providing a training
3 set of expressions of a second person who is different from the first person; and

4 a transformation processor configured to derive a transformation function
5 from the training set of expressions and corresponding expressions from the first
6 set of expressions.

7
8 **25. (ORIGINAL)** The expression transformation system of claim 24,
9 wherein the transformation processor comprises a linear transformation processor.

10
11 **26. (ORIGINAL)** The expression transformation system of claim 24
12 further comprising a synthetic set of expressions embodied on a computer-
13 readable medium, the synthetic set of expressions being derived by applying the
14 transformation function to the code book expressions.

15
16 **27. (ORIGINAL)** The expression transformation system of claim 24,
17 wherein the transformation function compensates for differences in the size and
18 shape of the faces of the first and second persons.

19
20 **28. (ORIGINAL)** The expression transformation system of claim 24,
21 wherein the transformation processor derives the transformation function by:

22 representing each expression as a $3m$ -vector that contains x , y , z
23 displacements at m standard sample positions; and

24 computing a set of linear predictors a_j , one for each coordinate of g_a , given
25 a set of n expression vectors for a face to be transformed, $g_{a1\dots n}$, and a

1 corresponding set of vectors for a target face, $g_{b1\dots n}$, by solving $3m$ linear least
2 squares systems of the following form:

3 $a_j \cdot g_{ai} = g_{bi}[j], i = 1\dots n$

4
5 **29. (ORIGINAL)** A facial expression transformation system
6 comprising:

7 a transmitter comprising:
8 a facial illumination system that is configured to provide multiple different
9 light sources at the same time for illuminating a subject's face;

10 a data-capturing system configured to capture both structure data and
11 reflectance data from the subject's face when illuminated by the facial
12 illumination system; and

13 a first code book of synthetic expressions that have been synthesized by:
14 receiving a training set of expressions provided by the subject;
15 computing a transformation function using the training set of expressions
16 and corresponding unsynthesized code book expressions; and

17 applying the transformation function to all of the expressions in the code
18 book; and

19 a receiver communicatively linked with the transmitter and comprising:
20 a reconstruction module for reconstructing facial images; and
21 a second code book containing the same synthetic expressions as the first
22 code book; and

23 the transmitter being configured to:
24 capture additional expressions of the subject;

1 search the first code book for a corresponding or near matching expression;
2 and

3 transmit an index of a corresponding or matching code book expression to
4 the receiver for facial image reconstruction by the reconstruction module.

5
6 **30. (ORIGINAL)** The expression transformation system of claim 29,
7 wherein the illumination system comprises at least one polarized light source.

8
9 **31. (ORIGINAL)** The expression transformation system of claim 29,
10 wherein the illumination system comprises multiple polarized light sources.

11
12 **32. (ORIGINAL)** The expression transformation system of claim 29,
13 wherein the illumination system comprises a patterned light source configured to
14 project a pattern onto the subject's face.
b2

15
16 **33. (ORIGINAL)** The expression transformation system of claim 29,
17 wherein the illumination system comprises an infrared patterned light source
18 configured to project a pattern onto the subject's face.

19
20 **34. (ORIGINAL)** The expression transformation system of claim 29,
21 wherein the different light sources are all infrared light sources.

22
23 **35. (ORIGINAL)** A method of animating facial features comprising:
24 defining a subdivision surface that approximates geometry of a plurality of
25 different faces; and

1 fitting the same subdivision surface to each of the plurality of faces.

2

3 **36. (ORIGINAL)** The method of claim 35, wherein said defining

4 comprises defining the subdivision surface with a coarse mesh structure.

5

6 **37. (ORIGINAL)** The method of claim 36, wherein the coarse mesh

7 structure comprises a triangular mesh.

8

9 **38. (ORIGINAL)** The method of claim 35, wherein said fitting

10 comprises performing a continuous optimization operation over vertex positions of

11 the subdivision surface.

12

13 **39. (ORIGINAL)** The method of claim 35, wherein said fitting

14 comprises fitting the subdivision surface to the faces without altering the

15 connectivity of a mesh that defines the subdivision surface.

16

17 **40. (ORIGINAL)** The method of claim 35, wherein said fitting

18 comprises minimizing a smoothing functional associated with a mesh that defines

19 the subdivision surface.

20

21 **41. (ORIGINAL)** The method of claim 35, wherein said fitting

22 comprises selecting one or more constraints associated with a mesh that defines

23 the subdivision surface and fitting those constraints directly to corresponding

24 points on the faces.

1 **42. (ORIGINAL)** The method of claim 41, wherein the constraints are
2 associated with one of the eyes, nose and mouth.

3

4 **43. (ORIGINAL)** The method of claim 35, wherein said fitting
5 comprises minimizing a functional that includes terms for distance, smoothness,
6 and constraints.

7

8 **44. (ORIGINAL)** The method of claim 35, wherein said fitting
9 comprises solving a sequence of linear least-squares problems.

10

11 **45. (ORIGINAL)** One or more computer-readable media having
12 computer-readable instructions thereon which, when executed by one or more
13 computers, cause the one or more computers to implement the method of claim 35.

14

15 **46. (CURRENTLY AMENDED)** A method of animating facial
16 features comprising:

17 defining a subdivision surface that approximates geometry of a plurality of
18 different faces;

19 fitting the same subdivision surface for only one expression to each of the
20 plurality of faces to establish a correspondence between the faces for a plurality of
21 expressions; and

22 using the correspondence between the faces to transform an expression of
23 one face into an expression of another face.

1 **47. (CURRENTLY AMENDED)** A method of animating facial
2 features comprising:

3 measuring 3-dimensional data for a plurality of different faces to provide
4 corresponding face models;

5 defining only one generic face model that is to be used to map to each
6 corresponding face model;

7 selecting a plurality of points on the generic face model that are to be
8 mapped directly to corresponding points on each of the corresponding face
9 models; and

10 fitting the generic face model to each of the corresponding face models for
11 only one expression to establish a correspondence between the faces for a plurality
12 of expressions, said fitting comprising mapping each of the selected points directly
13 to the corresponding points on each of the corresponding face models.

14
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15 **48. (ORIGINAL)** The method of claim 47, wherein:

16 said defining comprises defining a subdivision surface from a base mesh
17 structure, the subdivision surface containing a plurality of vertices and
18 approximating the geometry of the face models; and

19 said fitting comprises manipulating only the positions of the vertices of the
20 subdivision surface.

21
22 **49. (ORIGINAL)** The method of claim 47, wherein said fitting
23 comprises manipulating a base mesh that defines a subdivision surface.

1 **50. (ORIGINAL)** The method of claim 47, wherein said fitting
2 comprises manipulating a base mesh that defines a subdivision surface without
3 altering the connectivity of the base mesh.

4

5 **51. (ORIGINAL)** The method of claim 47, wherein said measuring
6 comprises using a laser range scan to measure the 3-dimensional data.

7

8 **52. (PREVIOUSLY PRESENTED)** A facial expression transformation
9 method comprising:

10 defining a code book containing data defining a first set of facial
11 expressions of a first person;

12 providing data defining a second set of facial expressions, the second set of
13 facial expressions providing a training set of expressions of a second person who
14 is different from the first person;

15 **b2** deriving a transformation function from the training set of expressions and
16 corresponding expressions from the first set of expressions, wherein the deriving
17 of the transformation function comprises:

18 representing each expression as a $3m$ -vector that contains x, y, z
19 displacements at m standard sample positions; and

20 computing a set of linear predictors a_j , one for each coordinate of g_a ,
21 given a set of n expression vectors for a face to be transformed, $g_{a1\dots n}$, and a
22 corresponding set of vectors for a target face, $g_{b1\dots n}$, by solving $3m$ linear
23 least squares systems of the following form:

24
$$a_j \cdot g_{ai} = g_{bi}[j], i = 1\dots n,$$

25

1 wherein said computing comprises using only a subset of points for
2 each g_{aj} ; and

3 applying the transformation function to the first set of expressions to
4 provide a synthetic set of expressions.

5
6 **53. (PREVIOUSLY PRESENTED)** The method of claim 52, wherein
7 said using comprises using only points that share edges with a standard sample
8 point under consideration.

9
10 **54. (PREVIOUSLY PRESENTED)** A facial expression transformation
11 method comprising:

12 defining a code book containing data defining a first set of facial
13 expressions of a first person;

14 providing data defining a second set of facial expressions, the second set of
15 facial expressions providing a training set of expressions of a second person who
16 is different from the first person;

17 deriving a transformation function from the training set of expressions and
18 corresponding expressions from the first set of expressions, wherein the deriving
19 of the transformation function comprises:

20 representing each expression as a $3m$ -vector that contains x , y , z
21 displacements at m standard sample positions; and

22 computing a set of linear predictors a_j , one for each coordinate of g_a ,
23 given a set of n expression vectors for a face to be transformed, $g_{a1...n}$, and a
24 corresponding set of vectors for a target face, $g_{b1...n}$, by solving $3m$ linear
25 least squares systems of the following form:

$$a_j \cdot g_{ai} = g_{bi}[j], i = 1 \dots n;$$

controlling the spread of singular values when computing a pseudoinverse to solve for the a_j ; and

applying the transformation function to the first set of expressions to provide a synthetic set of expressions.

55. (PREVIOUSLY PRESENTED) The method of claim 54, wherein said controlling the spread comprises zeroing out all singular values less than $\alpha\sigma_1$, where σ_1 is the largest singular value of the matrix.

56. (PREVIOUSLY PRESENTED) A facial expression transformation method comprising:

defining a code book containing data defining a first set of facial expressions of a first person;

providing data defining a second set of facial expressions, the second set of facial expressions providing a training set of expressions of a second person who is different from the first person, wherein said providing data defining a second set of facial expressions comprises:

illuminating the second person's face with illumination, said illuminating comprising:

using multiple light sources, one of which projecting a pattern on the second person's face from which the structure data can be ascertained;

at least one of the light sources comprising an infrared light source;

at least one of the light sources being polarized; and

1 contemporaneously capturing structure data describing the face's
2 structure and reflectance data describing reflectance properties of the face
3 from the illumination, said capturing comprising using a camera having a
4 polarizer that suppresses specularly-reflected light so that diffuse
5 component reflection data is captured;

6 deriving a transformation function from the training set of expressions and
7 corresponding expressions from the first set of expressions; and

8 applying the transformation function to the first set of expressions to
9 provide a synthetic set of expressions.

10
11 **57. (CURRENTLY AMENDED)** A facial expression transformation
12 method comprising:

13 defining a code book containing data defining a first set of facial
14 expressions of a first person;

15 providing data defining a second set of facial expressions, the second set of
16 facial expressions providing a training set of expressions of a second person who
17 is different from the first person, [[,]] wherein said providing data defining a
18 second set of facial expressions comprises:

19 illuminating the second person's face with a first polarized light
20 source that is selected so that specularly-suppressed reflective properties of
21 the face can be ascertained;

22 illuminating the second person's face with a second structured light
23 source that projects a pattern onto the face, while simultaneously
24 illuminating the face with the first polarized light source; and

capturing both specularly-suppressed reflection data and structure data from the simultaneous illumination; deriving a transformation function from the training set of expressions and corresponding expressions from the first set of expressions; and applying the transformation function to the first set of expressions to provide a synthetic set of expressions.

58. (PREVIOUSLY PRESENTED) The method of claim 57, wherein the light sources provide light at different frequencies.

59. (PREVIOUSLY PRESENTED) The method of claim 57, wherein the light sources provide infrared light.

60. (PREVIOUSLY PRESENTED) The method of claim 57, further comprising processing the captured data to provide both (a) data that describes dimensional aspects of the face and (b) data that describes diffuse reflective properties of the face.

61. (PREVIOUSLY PRESENTED) A facial expression transformation method comprising:

defining a code book containing data defining a first set of facial expressions of a first person;

providing data defining a second set of facial expressions, the second set of facial expressions providing a training set of expressions of a second person who

1 is different from the first person, wherein said providing data defining a second set
2 of facial expressions comprises:

3 illuminating the second person's face with multiple different light
4 sources;

5 measuring range map data from said illuminating;

6 measuring image data from said illuminating;

7 deriving a 3-dimensional surface from the range map data;

8 computing surface normals to the 3-dimensional surface; and

9 processing the surface normals and the image data to derive an
10 albedo map;

11 deriving a transformation function from the training set of expressions and
12 corresponding expressions from the first set of expressions; and

13 applying the transformation function to the first set of expressions to
14 provide a synthetic set of expressions.

15
16 **62. (PREVIOUSLY PRESENTED)** The method of claim 61, wherein
17 at least one of the light sources is polarized.

18
19 **63. (PREVIOUSLY PRESENTED)** The method of claim 61, wherein
20 all of the light sources are polarized.